LANDSAT CLASSIFICATION FOR
WILDLIFE HABITAT MANAGEMENT
AND RESEARCH PLANNING

Problem Analysis

INTEGRATED WILDLIFE INTENSIVE FORESTRY RESEARCH

Province of British Columbia

A cooperative project between the Ministries of Environment and Forests

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FOR
WILDLIFE HABITAT MANAGEMENT AND RESEARCH PLANNING

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Summary

As part of the Integrated Wildlife Intensive Forestry program for Vancouver Island, this problem analysis was designed to evaluate the ability of Landsat image data to provide a wildlife habitat classification system. Preliminary examination of the success of Landsat image data application indicated that image analysis is best suited for broad vegetational mapping, resource monitoring, and as the initial step in a multistage sampling process.

This report includes an introduction to the principles of Landsat and the description and capabilities of analogue and digital analysis techniques and systems.

To meet the objective, two study topics are recommended: (1) Development of a current habitat inventory for Vancouver Island using digital Landsat data and (2) Landsat image analysis comparison: Digital vs Visual. These study topics are designed to evaluate the suitability of a Landsat classification system for management and research development and research site selection.

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Table of Contents

Page

Summary i
Acknowledgements i
Table of Contents ii
List of Figures iv
List of Tables iv

1 INTRODUCTION 1

2 PROBLEM 1
2.1 The Initial Problem 1
2.2 The Problem Addressed 2

3 OBJECTIVE 3

4 THE LANDSAT SYSTEM 3
4.1 Introduction to Landsat 3
4.1.1 Description of Landsat 3
4.1.2 Analytical Systems 8
4.2 Visual Analysis Techniques and Systems 8
4.2.1 Description 8
4.2.2 Availability 9
4.3 Digital Analysis Techniques and Systems 10
4.3.1 Description 10
4.3.1.1 Radiometric Enhancement 10
4.3.1.2 Spatial Enhancement 10
4.3.1.3 Unsupervised Classification 11
4.3.1.4 Supervised Classification 11
4.3.1.5 Maximum Likelihood 12

4.3.2 Availability 13
4.3.2.1 Pacific Forest Research Centre 13
4.3.2.2 Canada Centre for Remote Sensing 16
4.3.2.3 MacDonald Dettwiler & Associates Ltd. 17
4.3.2.4 Petawawa National Forestry Institute 18

5 OTHER CONSIDERATIONS 20
5.1 UBC Image Analysis System 20
5.2 MOF Inventory Branch Landsat Project 20

6 STUDY TOPICS 21
6.1 Introduction 21
6.2 Development of a Current Habitat Inventory for Vancouver Island Using Digital Landsat Data 22
6.2.1 Rationale 22
6.2.2 Objective 23
6.2.3 Proposed Study Projects 23
6.2.3.1 Phase 1: Pilot Project 23
6.2.3.2 Phase 2: Major Analysis 24
6.3 Landsat Imagery Analysis Comparison: Digital vs Visual 24
6.3.1 Rationale 24
6.3.2 Objectives 25
6.3.3 Proposed Study Project 25

7 SUMMARY 26

8 LITERATURE CITED 27

9 APPENDIX 29

List of Figures

1. Typical daily Landsat orbit 5

2. Landsat data acquisition 6

List of Tables

1. Comparison of four Landsat image analysis systems 14

1 INTRODUCTION

As intensive forest management increases on Vancouver Island, knowledge about wildlife/intensive forestry interactions becomes critical to effective integrated resource management. One way of acquiring this knowledge is to develop a wildlife-oriented habitat classification system and then use this system to direct and develop the necessary research. As part of the Integrated Wildlife Intensive Forestry Research (IWIFR) program, this could provide a habitat classification system suitable for wildlife/forestry research planning. This problem analysis is a support project to other research topics and is designed to test and evaluate Landsat classification methodology.

2 PROBLEM

2.1 The Initial Problem

Initially, the problem analysis was directed towards determining whether or not the information available from Landsat imagery could provide a wildlife habitat classification system. The resulting classification system was to be used for research site selection and research result extrapolation. Preliminary examination of the nature of the information available from Landsat imagery, its limitations and the existing scope of successful application indicates that the development of an animal-oriented wildlife habitat classification system through the use of Landsat imagery is not possible.

Landsat imagery is most "suited to broad resource inventory and extensive management of such resources, which do not require detailed information" (Lee 1974:141). A review of the literature indicates that successful Landsat image applications involve mapping broad vegetational classes and monitoring landscape changes. More recently, it has shown promise as the initial stage in a multi-stage sampling procedure (Tomlins, pers. comm.). In view of this, its potential as a useful tool warranted further investigations. The focus of

this investigation was therefore aimed at revealing a problem for which this solution could be applied. It was " ... a solution in search of a problem" (Giles 1969:3).

2.2 The Problem Addressed

For many years, the Ministry of Forests (MOF) and logging companies have been using their forest inventories for single use management planning. In recent years however, a growing demand on our forest resources has created the need to develop integrated management plans which can accommodate the various uses.

Successful management depends upon the wildlife biologist being able to assess the current state of the habitat. At present, a wildlife habitat inventory for Vancouver Island is not available. The data necessary to develop an inventory is either not known or in a format which makes collation difficult and time-consuming. Available forest inventories, although comprehensive, are of limited value to the wildlife biologist due to the following factors: 1) quantity of data; 2) lack of standardized format (e.g. scale, cover type classes); 3) the boundaries of wildlife and forestry management units differ; 4) inappropriate data available; and 5) delay in information update (Davies, pers. comm.). The size of Vancouver Island, the inaccessibility of areas and rapid alteration of large areas of the environment by widespread logging practices add to the problem.

Such fundamental questions as: 1) What is the ratio of mature to immature forest on Vancouver Island? 2) What are the spatial relationships of stands of various ages and conditions? 3) Where are these located? and 4) How are they changing? are not easily answered at present.

Since available large-scale data are difficult to handle for an area the size of Vancouver Island, we need a method which can provide a current overview of the area to form the basis for or to supplement research planning and management decisions.

An understanding of the interrelationships of species and habitat is fundamental to the IWIFR program. With the high cost of research, research site selection is critical but difficult on an area as large as Vancouver Island. In addition, specific spatial complexes of habitats and other critical areas are difficult to locate and, hence, make the development and location of site specific research topics difficult. Availability of a current habitat type map would ease these problems. This problem analysis attempts to address these problems.

3 OBJECTIVE

The objective of this problem analysis is to determine if Landsat imagery can provide a classification system suitable for management and research planning and research result extrapolation. This objective is a revision of the one originally proposed and is designed to address the scope of the revised problem.

4 THE LANDSAT SYSTEM

4.1 Introduction to LANDSAT

4.1.1 Description of LANDSAT

NASA's (National Aeronautics and Space Administration) launching of Landsat-1 (formerly called ERTS-1) in July 1972 made available for the first time multispectral satellite imagery of our earth resources on a comprehensive repetitive basis. Subsequent launchings of Landsat-2 in April 1975 and Landsat-3 in March 1978 have provided a continuity to data acquisition. In January 1977, technical problems resulted in Landsat-1 being deactivated. Intermittent problems with Landsat-2 created the need to alternate between Landsat-2 and -3 in an attempt to prolong the length of time over which data could be obtained. It is projected that Landsat D (to be called Landsat-4 upon successful launch) will be operable in 1982 (Tomlins, pers. comm.). This satellite will scan a greater number of spectral bands than Landsat 1-3 and will provide an estimated ground resolution of 30 meters.

Landsat (1-3) has a sun-synchronous orbit tracking north to south along an easterly deviating flight path (16^{o} from true north) (Tomlins, pers. comm.) at an altitude of approximately 920 km (Figure 1). Each satellite completes 14 orbits per day 103 min/orbit) with a nominal 9:30 a.m. crossing of the equator on the descending path (NASA 1976, Section 5). Regular coverage of daylight areas is provided every 18 days. Coverage for Vancouver Island occurs at approximately 10:15 a.m.

The satellites carry a multispectral scanner (MSS) and a return beam vidicon (RBV) camera system (see NASA [1976] for information on RBV). Landsat-1 and -2 MSS respond in four spectral bands whereas the Landsat-3 MSS carries an additional band responding to thermal infrared radiation. The MSS sensor records reflected radiation in the visible and near infrared regions of the electromagnetic spectrum: Band 4 (0.5-0.6 um) approximates green light; Band 5 (0.6-0.7 um) approximates red light; Band 6 (0.7-0.8 um) and Band 7 (0.8-1.1 um) approximates near infrared light. Band 4 and 5 are generally used for vegetation studies (Lee, pers. comm.). A combination of Band 5 and 6 is best for analysis of vegetation difference in clear-cuts and among the various ages of the cuts (Murtha and Watson 1975). Band 7 is useful for distinguishing land from water (Lee, pers. comm.).

The satellite sensors scan, at right angles to the flight path, an area approximately 185 x 185 km (Figure 2). Due to the curvation of the earth, image sidelap is 14% at the equator and increases as higher latitudes are reached. Between 42 and 67 degrees latitude, image sidelap is between 67 and 75 percent. A Landsat scene has approximately 3000 scan lines: each scan having approximately 35 000 picture elements or pixels (NASA 1976, Appendix E). Each pixel represents an area of approximately 59 x 79 meters (approx. 1.5 acres).

In Canada, Landsat digital data is received and recorded at earth satellite stations in Prince Albert, Saskatchewan and Shoe Cove, Newfoundland. Canadian users can obtain data from the Canada Centre for Remote Sensing (CCRS) located in Ottawa, Ontario. Imagery is available in two

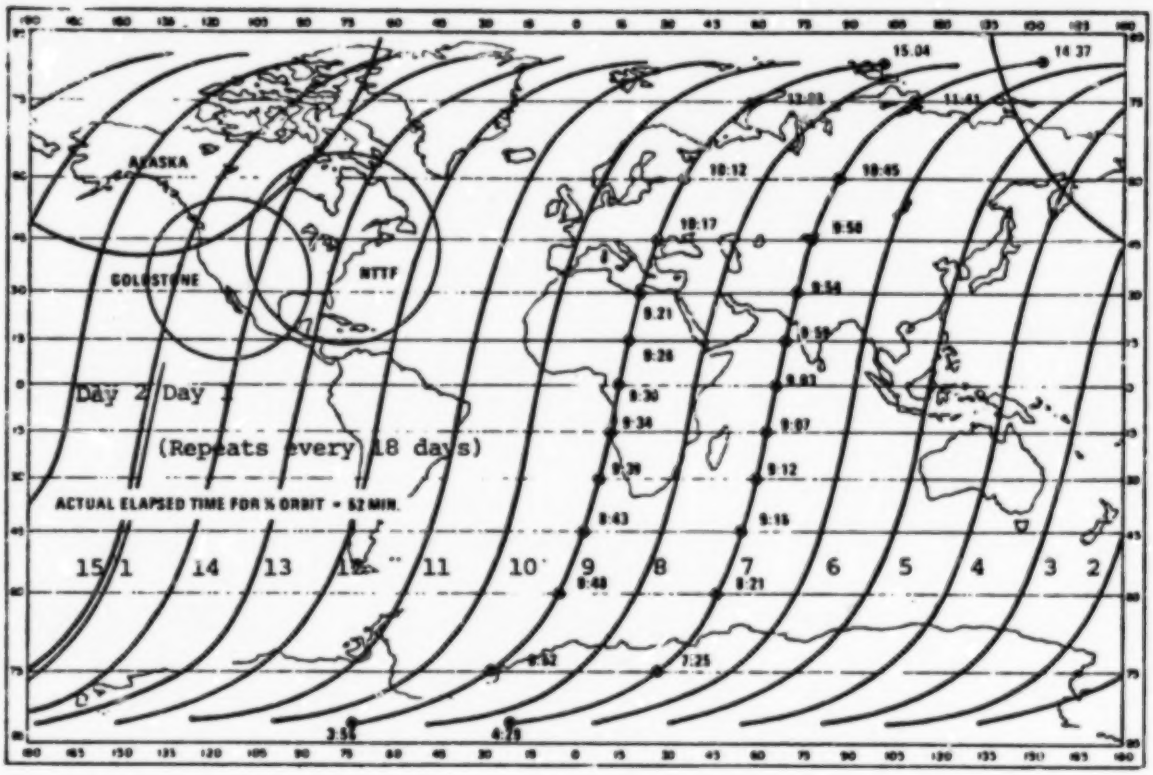

Figure 1. Typical daily Landsat orbit paths for a single day. Each day paths shift westward 160 km at the equator so that every 18 days the paths are repeated. Clock time indicates local clock time for various points in a typical orbit as a function of latitude. Compiled from NASA (1976) figures 2-6 and f-10 and Sabins (1978) figures 4-6.

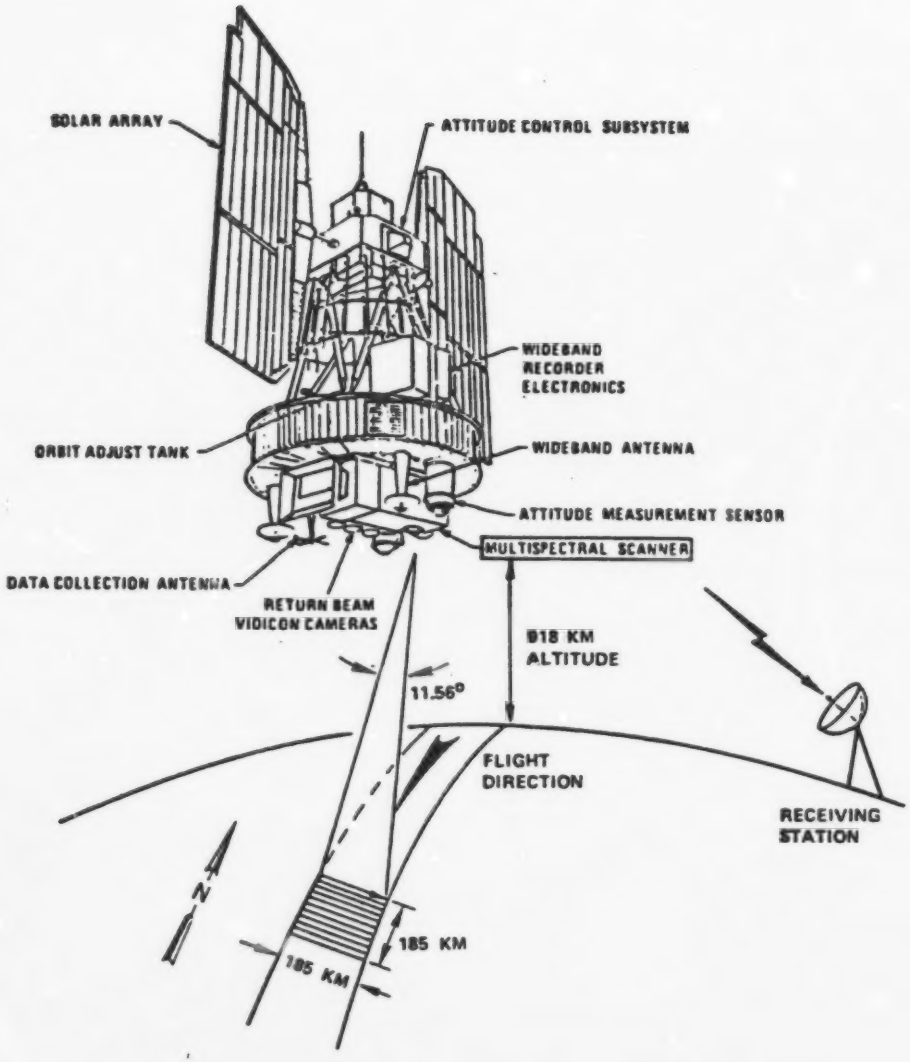

Figure 2. The multispectral scanner uses an oscillating mirror to continuously scan perpendicular to the space craft velocity. Six lines are scanned simultaneously in each of the four (Landsat 1 and 2) or five (Landsat 3) spectral bands for each mirror sweep. Radiation is sensed simultaneously by an array of six detectors in each of the spectral bands. Processing at the ground station transforms the continuous data stream into consecutive framed images. Compiled from NASA (1976) and Sabine (1978) figures 4.1 and 4.2.

formats: visual (paper prints, mosaics, transparencies) and digital (computer compatible tapes known as CCTs). The complete record of all Landsat imagery received to date is stored in archives and is available in microfiche format (called ISIFICHE) through the Integrated Satellite Information Services Ltd., Prince Alberta, Saskatchewan (Quenet 1979). Selection of image format is dependent upon the requirements of the user.

Due to the orientation of the flight path, CCT digital data were found to present problems when two scenes were superimposed or when relating the image information to NTS based maps. In order to correct this, CCRS developed an analytical procedure known as DICS (Digital Image Correction System). Using the digital data from one complete Landsat scene, DICS rotates, resamples and superimposes compatible NTS maps. Five geometrically corrected images with north-south orientation and a new pixel size of 50 x 50 meters are produced. One DICS tape represents 1/5 of a Landsat scene or 1/4 of a 1:250 000 NTS maps sheet.

Theoretically Landsat provides coverage of an area every 18 days but, due to atmospheric conditions, all imagery is not of satisfactory quality to be useful. For any Canadian geographic area, CCRS provides a list of images qualified by degree of cloud cover and spectral band quality.

To evaluate the application potential of Landsat imagery, it is important that the user be aware of the interpretative limitations inherent in the image.

First, spatial resolution is low. The smallest resolvable ground area available is limited by the pixel size. Unique features covering areas less than 0.6 ha (1.1 acre) cannot be detected. In practise, it may be "risky to depend on Landsat data for resolution smaller than 10 acres (4 ha)" (Parker no date:547). Also, the value ascribed to a pixel is the average of the reflected radiation within the resolvable area and the degree of difference in reflectivity between adjacent pixels affects the visual interpretation.

Second, similar reflectivity values may not indicate similar cover types and different reflectivity values may not indicate differences in cover types because of the effects of surface topography and sun position (Woodham, pers. comm.).

Visual interpretative inaccuracies can, however, be minimized if the user remembers that reflectivity is affected by 1) sun angle, 2) cloud cover, 3) slope, 4) aspect, and 5) vegetation wetness or dryness. Quenet (pers. comm.) suggests restricting training site selection and subsequent application to a major ecozone or terrain stratification.

On the basis of the above considerations it appears that the success of a Landsat classification system depends upon the image analysts's familiarity with the study area and the amount of ground truthing available.

4.1.2 Analytical Systems

Landsat image data can be analyzed visually or digitally. The analogue form provides the data for the visual analysis while the digital form provides the data for digital analysis.

4.2 Visual Analysis Techniques and Systems

4.2.1 Description

Paper prints and mosaics are useful for broad-scale planning (Quenet 1979). Major features such as forest, snow, water, logged and burned areas can be interpreted. Gross area summaries, using manual planimetric or dot-counting methods, are also possible (Lee, pers. comm.). Using sequential date imagery, major environmental disturbances can be identified.

The resultant classification map can be drafted directly on the paper print or on a mylar or acetate sheet. Its scale is dependent upon the scale of the paper print used for analysis. Prints can be ordered in any scale: the standard scales reproduced are (1) 1:1 000 000, (2) 1:250 000 and (3) 1:125 000 (Sec. 9.1).

Paper print analysis is fast and inexpensive. There are, however, limitations which may restrict its usefulness: (1) data is difficult to transfer to maps; (2) classification of forest types is difficult; and (3) resolution is decreased when compared with digital data. Its advantage is its low cost.

Visual interpretation of Landsat images can also be made using positive transparencies. By projecting the images on a screen or over existing maps features can be drafted or compared. Sequential date data can also be easily mapped by using an epidiascope or vertical light projector.

An instrument known as the colour additive viewer (CAV) is used to increase the amount of visual information available for interpretative analysis when using transparencies. The CAV allows the image analyst to enhance the contrast between the imagery features by adjusting the colour combinations and intensities projected through the B/W Landsat transparency. Two scales typically used are: 1) 1:250 000 and 2) 1:150 000. The former is suitable for identifying large area features and their spatial relationships; the latter enables more detailed information to be extracted from the imagery (Sec. 9.2.3.1). The success of the visual image analysis classification is dependent upon the contrast quality of the transparencies, the image analyst's experience with the colour additive viewer and the availability of ground truth information.

Once the desired features have been identified, transfer of the information from the enhanced image into a useable format is possible in three ways. A mylar can be produced by placing a mylar sheet on the visual screen of the CAV and then tracing the feature boundaries directly onto the sheet. Acetate prints are possible using a zoom stereo transfer scope. The colour additive viewer can also be equipped with an automatic exposure control which enables photographs to be taken of the enhanced image. However, a mosaic of several image photographs can present a drafting problem (Watson, pers. comm.). Using the CAV, a fast and inexpensive method for visually interpreting the current state of the land resource is possible.

4.2.2 Availability

Paper print analysis does not require an image analysis system. Once the paper print has been acquired, the analysis can be undertaken by the manpower available. No special training is necessary; however, a familiarity with photo and/or infrared interpretation would be advantageous.

Image analysis using transparencies requires an instrument for projecting the image. The UBC Faculty of Forestry has a CAV which is primarily used as a teaching aid and for research (Murtha, pers. comm.). This system is available to outside researchers on a 'first come' basis and at an hourly rate. A technician is also available for consultation. Training time can be minimized by contracting an experienced user. Contact has been made with Kent Watson, International Range Remote Sensing Ltd. He is experienced with the colour additive viewer facilities at UBC and his services ($250 per day plus expenses) are available by contract.

4.3 Digital Analysis Techniques and Systems

4.3.1 Description

Digital (computer-based) analysis requires the use of a Landsat image analysis system. A review of the literature indicates that the techniques most widely used for digital analysis of Landsat images are radiometric enhancement, spatial enhancement, unsupervised classification, supervised classification and maximum likelihood classification.

4.3.1.1 Radiometric Enhancement

Radiometric enhancement is used by the image analyst to enhance the contrast between features. The intensities are increased by applying linear, exponential, square, logarithmic or square root functions to the radiometric values. Enhancement is also possible by stretching the range of the current spectral data to the range limits. This effectively increases the difference between data values. By increasing the difference between the values, it is easier to visually identify the features which they represent. This technique is used in conjunction with unsupervised, supervised, and maximum likelihood classification analyses and is principally a visual aid.

4.3.1.2 Spatial Enhancement

Spatial enhancement increases the homogeneity of a region or classification. This is achieved by eliminating odd (unhomogeneous) pixels

within the classification. The elimination of these pixels increases the visual interpretation of the spatial patterns and relationships of the classes; of course, information is lost in the process. Its application is cosmetic and this should be kept in mind when interpreting the product. This technique is applied after a classification analysis (unsupervised, supervised or maximum likelihood) has been performed.

4.3.1.3 Unsupervised Classification

Unsupervised classification examines image data and selectively separates, using various forms of statistical analysis, spectrally identifiable classes. Ground truth information is not used. The number of classes can be prespecified or computed. Separation or combination of classes enables refinement of the classification.

Unsupervised classification, however, has a limited interpretative value (Lee et al. 1977). When the relationship between spectral value and cover type is not fundamental to the interpretation, successful application can be achieved (Thompson et al. 1980). This is rarely the case. Usually, interpretation is dependent upon the ability to accurately relate the spectral characteristics to the actual cover types. The inability of this procedure to take into account the inherent limitations related to spectral reflectivity and the a priori knowledge of the image analyst reduces the accuracy attainable.

This process requires minimal operator intervention and is therefore fast and economical. The results can be used as a preliminary overview of an area. It appears that the purpose most suited for this type of analysis is one of providing the initial discriminating stage of a supervised classification.

4.3.1.4 Supervised Classification

Supervised classification allows the user to define an area (known as a training site) of known cover types. The computed spectral value (known as the spectral signature) from the training sites is subsequently used to

classify area(s) with similar spectral characteristics. The range of the spectral signature is a function of the homogeneity of the training site. This type of analysis gives the user the ability to control the analysis and, therefore, the accuracy and interpretative value correspondingly increases. The success of a classification system is dependent upon the amount of ground truthing information available for the area.

Refining the training sites is the most difficult and time consuming process in the analysis. The problem can be separated into two functions: (1) location of survey results (if even available) on standard maps and (2) accurate transfer of boundaries into the computer. Training sites should be as large and homogeneous (i.e. representative of the cover type of concern) as possible (Tomlins, pers. comm.). In practice, however, homogeneity is not always possible and the statistics from these areas (spectral signature) may result in classification inaccuracies. Two classification anomalies include: (1) unclassification of areas (spectral signature too narrow) and (2) overlapping classification of areas (spectral signature too wide). A maximum likelihood classification, when available, is routinely applied in a supervised classification to minimize the problem of overlap.

A review of the literature suggests that supervised classification is effective and has been used for a wide range of applications. Potential users should be aware that the computer time required and, consequently, the cost of analysis is dependent upon a number of factors in the study: (1) area, (2) number of CCT required, and (3) the number of and the cover types to be identified. Woodham (pers. comm.) remarked that due to economic factors and the amount of ground truthing required to create a large number of classes, statistically meaningful classification systems rarely handle more than eight classes. It is, therefore, extremely important to evaluate the potential usefulness of the information when developing a project.

4.3.1.5 Maximum Likelihood

Maximum likelihood classification, using the spectral signature of a

previous classification as a base, examines and reassigns areas of overlap to one or another of the classes. Accordingly, this refines the resultant classification system.

4.3.2 Availability

The Landsat image analysis capabilities of four image analysis systems will be discussed:

Pacific Forest Research Centre - GEMS 300
Canada Center for Remote Sensing - Image 100
MacDonald, Dettwiler & Associates - IAS
Petawawa National Forestry Institute - ARIES

All support unsupervised, supervised classification, maximum likelihood classification and radiometric enhancement capabilities. PFRC's GEMS 300 and CCRS's Image 100 are the only two analysis systems which support the capability of spatial enhancement. The difference between analysis systems is mainly the speed with which the analysis is performed. This is a function of the system hardware and software (mathematical models). For example, the image analysis systems, GEMS 300 and Image 100, use a migrating means technique for unsupervised classification while the ARIES image analysis system uses a maximum likelihood classification. Ramifications of differences such as these, the availability of each system and the format of output available will be discussed. Table 1 compares the four systems.

4.3.2.1 Pacific Forest Research Centre

Accessibility

Available in Victoria at the federal Pacific Forest Research Centre is the image analysis system known as GEMS (Geographic Monitoring System). This system is available through a cooperative program association (Lee, pers.

Table 1. Comparison of four Landsat image analysis systems

Institute	Pacific Forest Research Centre	Canada Centre for Remote Sensing	McDonald, Dettwiler & Associates, Ltd.	Petawawa National Forestry Institute
Location	Victoria, B.C.	Ottawa, Ont.	Richmond, B.C.	Petawawa, Ont.
System	GEMS 300	Image 100	Image Analysis System	ARIES
Screen Size	256 x 256	512 x 512	256 x 256	256 x 256
Analysis	4 channels	8 channels	4 channels	8 channels
Video Display	3 channels	3 channels	3 channels	3 channels
Output	(Manual) Photograph of video screen	Image Recorder Photographic film	Image Recorder Photographic film	Image Recorder Photographic film
Advantages	Location Cost	Analysis techniques Output format	Analysis techniques Location	Analysis techniques
Disadvantages	Speed of analysis Output format	Scheduling for computer time Location	Cost of computer time	Location

comm.). Lee, a primary user of the system, has indicated his willingness to undertake the image analysis. His availability is subject to approval by the project supervisor (Acting Project Supervisor - Jim Dangerfield).

Capability

GEMS 300 is capable of analyzing 4 channels (4 spectral bands) and visually displaying 3 channels at one time. The area accurately displayed on the video screen is 256 x 256 pixels (i.e. 1:1 pixel ratio). The displayed area is approximately 1/35th of a DICS tape area. To display an area greater than 256^2 pixels, alternate pixels from the X and Y direction are deleted from the screen.

Digital analysis and processing of large areas (i.e. one DICS area) are relatively slow using GEMS 300 (Lee, pers. comm.). Unsupervised classification uses a migrating means technique for analysis. This technique is a 'black-box' process and does not provide the user with an interpretation of the analysis. The validity of the mathematical model is also questioned. These factors are thought to limit the interpretive value of the unsupervised classification analysis.

On this system there are two techniques available for refining the spectral signature of a supervised classification training site: Spectral scattergram slicing and scatterplotting. Spectral scattergram slicing involves grouping a spectral graph into homogeneous components. Scatterplotting is the delineation of a spectral signature of graphing the intersection of two spectral bands. Although the latter is the preferred technique, both are time-consuming. It takes 2-3 days to perform a supervised classification analysis on one 256 x 256 pixel area. The time required to classify a whole DICS tape is increased by the necessity to manually compute the vectors which define the area of the Landsat image data to be displayed on the video screen. Sub-classification is only possible by defining area blocks and applying an 'and' analysis. This process is time consuming and may not provide the desired results. Visual delineation is possible using a

track-ball driven cursor. Whichever analytical method is employed, the usefulness of the information is limited by the output presently available on the GEMS system.

Output

The output is limited to manually photographing the image displayed on the video screen. Due to a lack of software, the digital analysis (thematic map) cannot be recorded onto magnetic tape (CCT). This software service is being discussed but it is not known when it will be available (Van der Wereld, pers. comm.). Therefore, thematic map reproduction of a large area and at a constant scale is limited.

4.3.2.2 Canada Centre for Remote Sensing

Accessibility

The Canada Centre for Remote Sensing located in Ottawa, Ontario houses the image analysis system known as Image 100. This system is available for research purposes to anyone in Canada. Consequently the demand for service is great and scheduling is a problem.

A three month time delay from request to service has been suggested (Lee, pers. comm.). Lee of the PFRC has expressed his willingness to assist in a co-op program and serve as a computer operator. Geoff Tomlins of the CCRS will act as liaison if a cooperative program directly with CCRS is desired. It is uncertain at this time if CCRS is able to provide a computer operator.

Capability

The Image 100 system is much more sophisticated than the GEMS 300. It is capable of 8 channel analysis and 3 channel visual display on a video screen area of 512 x 512 pixels. Eight channel analysis allows a more refined classification system. Sixteen classifications are possible thereby

decreasing the spectral signature inaccuracies between ecozones. In addition, the ability to overlay summer and winter imagery enables hardwood and softwood differentiation. Unsupervised classification is performed using the migrating means technique. Limitations to this technique have been previously discussed (see p. 17). Spectral histogram slicing with immediate visual update make defining supervised classification training sites relatively easy (Tomlins, pers. comm.). Sub-classification of an area is also possible. This is important for subunit classification summaries.

Spatial enhancement is available on the Image 100 system. A user-defined square matrix moves over the classified area in a 'box-car' fashion, examining and reclassifying odd pixels (Lee, pers. comm.). The disadvantage of this method is that no minimum pixel number can be specified.

Output

CCRS is the major Landsat imagery distribution centre in Canada. Various formats and scales are available (Sec. 9.1). Thematic map reproduction turn-around time is two to three months (Tomlins, pers. comm.).

4.3.2.3 MacDonald Dettwiler & Associates Ltd.

Accessibility

MacDonald Dettwiler & Associates Ltd. (MDA), a manufacturer and retailer of Landsat hardware, is located in Richmond, B.C. and houses the Landsat Imagery Analysis System (IAS). Their services are available on a contract basis. They provide, depending on the requriements of the customer, computer engineers at various levels of expertise for consultation. The cost of computer time is $90 per hour.

Capability

The functional capabilities of the IAS include geometric correction and radiometric correction in addition to those outlined in section 4.3.1.

Radiometric correction involves manipulation of the digital data to adjust for the effect from haze and sun angle (Orth et al. 1978). The mathematical algorithms used for analysis are reliable and efficient (Quenet, pers. comm.). An image recorder registers the output on to photographic film. These can then be reproduced into conventional formats. Complete details of these functions are given by Orth et al. (1978).

At present, the screen available is 256 x 256 pixels. MDA is however currently engaged in a mass technological update of their system. This update will include an increase in screen size to 512 x 512 pixels, the implementation of Canada Centre for Remote Sensing software programs presently used and, in preparation for Landsat D image analysis, the Landsat D software programs. This system update is projected to be operational in the fall of 1981.

To assess the operational capabilities of the system, a cost estimate based on the proposed criteria outlined in Section 6 has been requested. A reply has not been received.

4.3.2.4 Petawawa National Forestry Institute

Accessibility

Housed in Petawawa, Ontario at the Petawawa National Forestry Institute (PNFI) is the Applied Resources Image Exploitation System (ARIES). A cooperative program is possible with the assistance of J. Lee of the PFRC. Lee is willing to act both as a liaison between this federal agency and the Ministry of Forests and as an image analyst operator. Lee has worked on this system and is familiar with the PNFI personnel and ARIES' capabilities.

Capability

Like the Image 100 system, ARIES is able to analyze 8 channels of information. Visual display is limited to 3 channels on a 256 x 256 pixel screen. This limitation is not as restrictive as that noted for GEMS 300 due to differences in their output services.

Digital image analysis is relatively simple, time-efficient and effective on the ARIES system due to the mathematical processing models used for classification analysis and the accessory programs available (Lee, pers. comm.). Unsupervised classification is performed by applying, as a final process, a maximum likelihood classification. Generated are n-dimensional histograms which provide the image analyst with a visual interpretation of the process. Letts (1978) provides a full description of the procedure. An awareness of the spectral distribution tends to increase the accuracy of the classification and promote easier training site selection (Lee, pers comm.). The problem (Sec. 4.3.2.1 'Capability' p. 18) associated with visually displaying a desired image area has been eliminated on this system by fully automating the procedure. This should simplify and decrease the time anticipated for supervised classification of a large area (i.e. many scenes). Unit boundaries can be delineated using a track-ball driver cursor.

On this system the spatial enhancement program allows the users to define the pixel number (1-25) and direction (i.e. diagonal, block) of the minimum area to be represented. Another program available for enhancing the visual interpretation of the classificaion system is a Modified Principle Component Analysis. This program produces a gradient scale within a colour classification. The greater the percentage represented the more intense the colour. ARIES is also able to overlay the National Topographic System's UTM grid. This facilitates easy visual comparison and area location. Classification summaries per UTM quadrant are also possible. Lee (pers. comm.) estimates 3-4 weeks are required to produce a classification system and inventory of Vancouver Island.

Output

Output, although not as varied as CCRS, is more efficient. Built within the ARIES system is an Image Recorder. This recorder registers any output from the analysis on photographic film. A processing program associated with the Image Recorder provides the users with two options: 1) is the whole image

to be recorded as one, or 2) should it be divided into quadrants and recorded as four separate pictures. The film is easily processed into 70 mm transparencies. These can then be projected or reproduced to the desired scale. There is no lengthy queque and the results of the analysis are available immediately.

5 OTHER CONSIDERATIONS

5.1 UBC Image Analysis System

At the University of British Columbia a research oriented digital image analysis facility exists as part of an Interdisciplinary Graduate Program in Remote Sensing. "This system consists of a Comtal Vision one image processing and display system connected, via a high speed link, to the Computing Centre's Amdahl 470 computer. Major system expansion is underway with the arrival of a VAX 11/780 computer and colour film writing and scanning equipment in late 1981. Current research users include faculty and graduate students from Computer Science, Forestry, Oceanography, Geophysics and Astronomy, Geography and Pathology. Possibilities exist for collaborative research projects, particularly as they relate to students pursuing advanced degrees. Enquiries can be directed to Dr. A.K. Mackworth, Director, Laboratory for Computational Vison, UBC., Department of Computer Science or Dr. P.A. Murtha, Chairman, UBC Council on Remote Sensing" (Woodham, pers. comm.).

5.2 MOF Inventory Branch Landsat Project

MOF Inventory Branch recently proposed a project using Landsat imagery to monitor changes occurring in B.C.'s forests (Nemeth, pers. comm.). Features of interest were areas of harvest, fire, and pest devastation. Eventually it was hoped that all of B.C. would be mapped into broad vegetation classes. Preliminary investigation suggested that the scope of the project was too ambitious for the technology presently available.

However, in preparation for this project, Inventory Branch, assisted by L.C. Goodfellow of CCRS, selected the best quality imagery from the growing

seasons of 1975 and 1979. For Vancouver Island, the imagery selected from 1975 was between June and September and from 1979 it was between July and October. Inventory Branch is willing to provide a table of this selected imagery (Nemeth, pers. comm.). Nemeth (pers. comm.) also suggested that financial cooperation may be arranged for the purchase of the selected DICS imagery data.

6 STUDY TOPICS

6.1 Introduction

The inability of Landsat image data to provide a wildlife-habitat classification system as originally perceived necessitated the re-evaluation of its applicability. Meetings were organized to correlate the foreseen applications of Landsat with its apparent capabilities. Participants of the meetings worked together to develop the following framework:

A. Habitat Classification System

The objective is to develop a classification system as refined as the methodology allows.

The following classes are known to be identifiable from Landsat image data. All classes are to be identified. The last two classes will be subdivided further.

(a) Water
(b) Snow
(c) Clear-cut and/or burned
(d) Mature timber
(e) Immature timber

B. Study Area and Resolution

The above classification will be used to classify the following areas.

(a) Vancouver Island
(b) Management Unit - Wildlife (Total - 13 for Vancouver Island)
(c) Watershed (Total - approximately 250 for Vancouver Island)
A watershed is a subunit within a Management Unit

C. Output

The products required are:

(a) Paper Print - Before Classification
Colour 1 (bands 4, 5 and 7) or B/W
scale 1:100,000
(b) Paper Print - After Classification
Thematic Map
scale 1:100,000
(c) Area Summary by Class for each Unit
Computer Printout or Table

The following study topics were designed as a means to acquire this information.

6.2 Development of a current Habitat Inventory for Vancouver Island using Digital Landsat Data

6.2.1 Rationale

At this time, a current inventory of the habitat is not accessible. As discussed earlier, this inaccessibility is due to the format and time-frame of the available information. In June 1978, MOF Inventory Branch acquired an

Intergraphics Design System to assist the Inventory Branch in its endeavour to provide a quantitative and yearly update of B.C.'s forest and rangeland inventory. However, the data base is not expected to be completed before 1983 and, therefore, its usefulness in providing the information that a research biologist requires, to aid in the development of management plans, is limited. To assess the current state of the habitat on Vancouver Island, the research biologist needs a quantitative summary of the habitat base and a mechanism to monitor its change.

6.2.2 Objectives

To develop useful habitat classification using Landsat imagery date.

To provide a classification inventory for Vancouver Island and per management unit (as defined by the Fish and Wildlife Branch).

To evaluate the methodology by comparing a current forest subunit inventory to the computer generated inventory for the same subunit.

6.2.3 Proposed Study Projects

Using selected imagery, perform a classification analysis with the aid of available ground truth information and assisted by a person familiar with Vancouver Island cover types. This project is divided into two phases: preliminary classification analysis and major classification analysis.
BENEFIT: This division is suggested to facilitate successful application of the developed classification.

6.2.3.1 Phase 1: Pilot Project

Using one preselected DICS tape, perform a classification analysis on an image analysis system within the locale (PFRC or MDA); Check with the researcher to ensure that the classification system developed is satisfactory; Refine if necessary.
BENEFIT: By using PFRC facilities costs are minimal; researchers are accessible for consultation; operational techniques can be refined.
COST: PFRC's GEMS 330 output capabilities are limited (Sec. 4.3.2.1).

6.2.3.2 Phase 2: Major Analysis

Based on the classification system established in Phase 1, analyze remaining DICS tapes.

In the time available to do this problem analysis, it appears that the ARIES system is the most efficient for a project of this scope.
NOTE: Awaiting submission of cost estimate from MacDonald, Dettwiler & Associates Ltd.; will re-evaluate upon arrival.

Using the classification system previously developed (Sec. 6.2.3.1) generate an inventory (area by class) for Vancouver Island; delineate management units and then generate classification inventory by management unit.
NOTE: Delineation of a boundary is one pixel wide; watersheds are too numerous and small to enable efficient and accurate inventories; watershed boundaries are better suited for delineation on paper prints.

Acquire a current forest subunit inventory obtained by conventional methods; delineate the subunit on digital Landsat imagery; compare computer generated inventory with the forest inventory.

6.3 Landsat Imagery Analysis Comparison: Digital vs Visual

6.3.1 Rationale

Digital Landsat Image classification analysis requires an available image analysis system, computer tapes (CCT), a computer operator, an image analyst (someone familiar with the area) and ground truth information (if available) of the area of concern. Visual analysis is possible using paper prints or positive transparencies. Both require ground truthing information and an image analyst to delineate and compute the area; the latter also requires the use of a colour additive viewer.

Lee (pers. comm.) suggests that for the proposed classifications previously indicated (Sec. 6.1) it may be more efficient and inexpensive to manually delineate the features into classes and compute their summaries. Of the three aforementioned analysis techniques, digital analysis involves the

greatest initial cost in terms of money, data acquisition turn around time and time for the analysis, to produce a habitat classification system for Vancouver Island. However, once the classification system has been established, subsequent analysis of the data is fast and the variability of the output format and scale increases the usefulness of the information. In contrast, visual analysis using paper prints is inexpensive, however, the singularity of the format limits its use (Sec. 4.2.1). The largest useable scale is 1:250 000 (Lee, Watson, pers. comm.). At this scale, visual interpretation is limited to an overview of broad classifications and the spatial patterning of the features. The accuracy with which these features can be delineated and the ability to delineate small areas are also limited by the scale.

Visual interpretation using positive-transparencies and the colour additive viewer is more expensive than paper print analysis, however, the usefulness and accuracy of the information obtained is increased due to the nature of the analysis (Sec. 4.2.1), the scale which can be used (1:150 000), and the output formats available. Both techniques of visual analysis provide only a map representing the classifications delineated. Any additional information desired requires further manipulation. It is difficult, at this time, to compare and evaluate the accuracy of the classification system which is produced using digital analysis or the colour additive viewer assisted visual analysis.

6.3.2 Objectives

To perform a cost-benefit analysis between digital analysis and visual interpretation.

6.3.3 Proposed Study Project

(a) Obtain a Colour 1 paper print (DICS) of desired scale; identify and delineate classes that correspond with those developed in Phase 1

(Sec. 6.2.3.1); generate inventory by performing area summary (using planimeter or dot-counter); compute costs.

(b) Contract Watson (Sec. 5.2) to perform a visual analysis of one Landsat scene of Vancouver Island using the colour additive viewer and produce a map representing the classification system developed.

(c) Compare and evaluate the cost and success of the classification systems developed in (a) and (b) and from the digital analysis (Sec. 6.2.3.1 and 6.2.3.2); calculate the classification inventory for (b) and compare with those generated from (a) and from the digital analysis (Sec. 6.2.3.2).

7 SUMMARY

Effective wildlife management and research planning requires the use of a habitat classification system. Acquisition of such a system requires utilization of techniques which provide data which are both current and accessible. In this problem analysis, the use of Landsat images is examined to determine its potential as a technique for the development of such a system.

It was found that while Landsat imagery cannot provide a detailed habitat classification system, it can provide a broad, cover type classification system which is current and accessible. Furthermore, the classification system can be inventoried quickly and efficiently. In addition, Landsat imagery provides a visual representation of the area of interest.

Two study topics have been recommended: (1) Development of a current habitat inventory for Vancouver Island using digital Landsat data and (2) Landsat image analysis comparison: Digital vs Visual. The knowledge acquired using Landsat imagery should aid the researcher in optimizing research direction and development and the manager in developing management plans.

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9 APPENDIX

9.1 Canada Centre for Remote Sensing Price List 30

9.2 Landsat Image Analysis: Examples of Application 31

9.3 Personnel Contacted 35

9.1 Canada Centre for Remote Sensing Price List

Effective July 1, 1979

IMAGE SIZE	TYPE	SCALE	FORMAT	B & W	COLOUR
185mm (7.3")	MSS	1:1,000,000	Paper	$ 9.00	$16.50
185mm (7.3")	RBV	1:500,000	Paper	$ 9.00	
371mm (14.6")	MSS	1:500,000	Paper	$22.00	$44.00
371mm (14.6")	RBV	1:250,000	Paper	$22.00	
742mm (29.2")	MSS	1:250,000	Paper	$38.50	$88.00
742mm (29.2")	RBV	1:125,000	Paper	$38.50	
70mm	MSS	1:3,369,000	Film Pos.	$35.00/4 band strip	
185mm (7.3")	MSS	1:1,000,000	Film pos.	$11.00	$20.00
185mm (7.3")	RBV	1:500,000	Film pos.	$11.00	
371mm (14.6")	MSS	1:500,000	Film pos.	$27.50	
371mm (14.6")	RBV	1:250,000	Film pos.	$27.50	

COMPUTER COMPATIBLE TAPES

TYPE	TRACKS	BPI	FORMAT	PRICE
4 Band MSS	9	1,600	Tape Set	$220.00 (tape and Band 5 print included)
DICS	9	1,600	Tape	$180.00/sub-scene

ISISFICHE		ISISFAX
$220.00/month	$2,220.00/year	negotiable

TIROS & NOAA PRICE LIST

IMAGE SIZE	SCALE	FORMAT	B & W
185mm (7.3")	1" = 160 mi.	Paper	$ 9.00
185mm (7.3")	1" = 160 mi.	Film Pos.	$11.00

SPECIAL SERVICE CHARGES

SEARCH AND CONSULTATION FEE: $25.00/hour

STANDING ORDERS: Into the hands of the carrier (including mail) within 48 hours from data acquisition: Unit Price x 2

RUSH ORDERS: To the carrier within 24 hours of reception of the order: Unit Price x 3

9.2 Landsat Image Analysis: Example of Application

9.2.1 Wetland Studies

9.2.1.1 Application of Landsat Data for Wetland Monitoring in the Fraser River Estuary (Tomlins, pers. comm.)

- cooperative program between Environment Canada and Canada Centre for Remote Sensing.

- current ground truthing provided by 1980 summer field study; a supervised digital analysis was performed on the Pacific Forest Research Centre's GEMS 300 in November, 1980.

- images from three months - May, August, and October - were analysed to determine which was the best month to distinguish the differences between vegetation types; August and October imagery could not discriminate between inland and foreshore marsh.

- using May imagery four classifications were mapped: 1) Low Brackish Marsh, 2) Inner Island Low Marsh, 3) Inner Island High Marsh, and 4) Foreshore Marsh.

- the author hopes that the resultant data base will be used toward an operational, satellite-based, wetland monitoring system for the Fraser River Estuary.

9.2.1.2 Simulation of Landsat D and Assessment of its Capabilities for the Inventory and Assessment of Wetlands for Management Purposes (EP 905 Research Branch)

Objective: To assess simulated Landsat D data capabilities and limitations for the ecological classification, inventory and assessment of wetlands for resource management.

- airborne MSS (multispectral scanner) was flown August 7-13, 1980 over an area in the Cariboo around Fletcher Lake, approximately 80 km southwest of Williams Lake.

- a concurrent, two week field study was undertaken to provide field verification for existing data and ground truthing for Landsat analysis.
- simulated Landsat D data are presently being analyzed using the Image 100 system (CCRS).
- completion of analysis projected for the end of April.
- final report estimated to be complete in mid-July.

9.2.2 Biophysical Classification

9.2.2.1 Terrestrial Studies Branch, Ministry of Environment, Victoria, B.C. (Fenger, pers. comm.)

1a. - presently mapping the northern 1/3 of B.C. to complete the Canada Land Inventory.
- acquired four 1:250,000 black and white Landsat Images (paper prints) of the area.
- although this was the scale at which the inventory maps were to be drawn, the user was not satisfied with the detail of information and found interpretation difficult.
- larger scale aerial photographs are therefore being used to provide the base for delineating features; the Landsat photographs acquired act as a check to ensure that the appropriate scale is being mapped.

1b. - Terrestrial Studies Branch personnel are also developing a biophysical data collection methodology for wildlife capability mapping.
- in conjunction, a pilot project, mapping biophysical wildlife capabilities in the Kootenays, is underway (scale 1:20,000); projected completion is Spring 1981.
- subsequent evaluation to be undertaken to determine efficiency and usefulness for mapping all of B.C. in this manner.

9.2.3 Monitoring Forest Resource

9.2.3.1 Mapping of Forest Clearcutting, South Vancouver Island from Landsat Imagery (Murtha and Watson 1975)

- three successive dates (1972-1974) of Landsat imagery were used to map the progression of clearcutting on southern Vancouver Island.

- the two mapping techniques used; single B/W band 5 imagery and colour combined 70 mm positive-transparency; the latter gave the best results.

- enlargement of the positive images to a mapping scale of 1:150,000 increased the detail of information available and enabled interpretation of 8 classes:

Old Growth	1. overmature - climax species (hemlock, cedar, Douglas fir).	
	2. mature - primarily Douglas fir.	
Second Growth	3. old second growth - primarily Douglas fir (100').	
	4. recent second growth - Douglas fir (30') and hardwood species.	
Recent Logging	5. canopy cover 75 - 100%)	based only % difference
	6. canopy cover 50 - 74%)	between the reflectance of
	7. canopy cover 10 - 49%)	bare ground and complete
	8. canopy cover 10% and) clear-cuts.	vegetation cover.

- the author concluded that monitoring clear-cut progression provides an estimate of their relative locations and their state of revegetation.

9.2.4 Multistage Sampling

9.2.4.1 A Remote Sensing Rangeland Classification for Lac-Du-Bois Grasslands, Kamloops, British Columbia (Watson and Murtha 1978)

- use of multidate and multiscale (Landsat 1:500,000 and 1:150,000; B/W aerial photographs 1:20,000; and colour-infrared aerial photographs 1:10,000)

remote sensing data was used to produce a rangeland classification.

- visual interpretation of Landsat imagery using the colour additive viewer provided a broad overview of the major range types and provided the first step in the inventory; aerial photographs and ground observations provided the detail required to identify range types and plant species present.

- a six level, hierarchial rangeland classification and map were produced of the Lac-du-Bois Range.

9.2.4.2 Multi-level Data Acquisition and Analysis for Wildlife Habitat Inventories (Fine and Dye 1978)

- investigation of the application of multiple resource data for a multipurpose inventory of Denali Planning Unit, Alaska.

- multi-level sampling techniques include: Landsat imagery (visual) 1:250,000 and digital data; aerial photographs 1:120,000 to 1:1,200; and ground truthing.

- case study indicates that regional data base established by this multi-level data acquisition technique is inexpensive (8-10 cents/acre for the study), depending on the level of accuracy.

9.2.4.3 A Multi-Stage Remote Sensing Program to Assess Reindeer Rangeland (Sims and Murth 1980) In Progress

- multi-stage monitoring of short and long-term changes of reindeer rangeland in the MacKenzie Delta Grazing Reserve, NWT.

- preliminary digital classification using CCRS Image 100 system provides plotter-produced digital maps to be used for comparison with aerial and field study information.

- the secondary level of information is to be acquired from high-altitude photographs; the high-altitude flight lines are designed to cross presently used and potential use areas of the reindeer rangeland.

- large scale subunit photo coverage will be obtained using 70 mm wingtip cameras providing high-resolution.

- field study sites chosen from the aforementioned large scale photos will provide ground truthing.

9.3 Personnel Contacted

Davies, Rick	Inventory Biologist, Ministry of Environment, Nanaimo.
Eastman, Don	Biologist 1/C Wildlife Research, Ministry of Environment, Victoria.
Ellis, Rick	Program Manager, Wildlife Habitat Research, Ministry of Forests, Victoria.
Fenger, Mike	Pedologist, Ministry of Environment, Victoria
Hebert, Darryl	Regional Wildlife Biologist, Ministry of Environment, Nanaimo.
Janz, Doug	Project Leader - Elk, Ministry of Environment, Nanaimo.
Johnston, Corrie	Sales Representative, MacDonald, Dettwiler & Assoc. Ltd. Vancouver.
Lee, Y. Jim	Researcher, Pacific Forest Research Centre, Victoria.
Murtha, Peter	Faculty of Forestry, University of British Columbia, Vancouver.
Nemeth, Joe	Remote Sensing Officer, Ministry of Forests, Vancouver.
Nyberg, Brian	Research Wildlife Ecologist, Ministry of Forests, Victoria.
Quenet, Robin	Manager - Inventory Methodology, Ministry of Forests, Victoria.
Redmond, Mary	Terrestrial Studies Branch, Ministry of Environment, Victoria.
Tomlins, Geoffrey	Canada Centre for Remote Sensing, Ottawa.

Townsend, Marika	Technical Assistant, Ministry of Environment, Nanaimo.
Van der Wereld, Toni	Computer Programmer, Pacific Forest Research Centre, Victoria.
Watson, Kent	Consultant, International Range Remote Sensing, Kamloops.
Woodham, Bob	Faculty of Forestry and Department of Computer Science, University of British Columbia, Vancouver.